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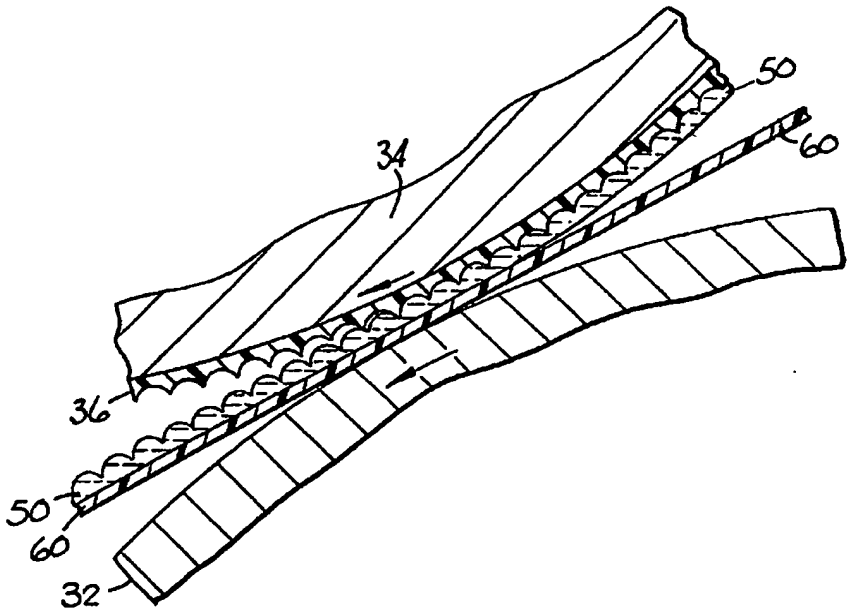

(57) Abstract

A method and apparatus for manufacturing lenticular optical systems comprises a transparent or opaque substrate (60) which is printed with a composite of lines to form one or more desired designs. The substrate is coated with a moldable material (52, 50) that is molded via a die (36) on a die cylinder (34) with a set of grooves parallel to the design lines on the die, so that each design is visible from certain viewing angles and not from other viewing angles. The moldable material is preferably a quick setting liquid, such as ultraviolet-curable plastic which can be hardened almost immediately to allow fast production techniques. The moldable material adheres to the substrate and detaches from the die as it exits the space between the die cylinder and impression cylinder (32).

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MAKING LENTICULAR OPTICAL SYSTEMS AND APPARATUS THEREFOR

FIELD OF THE INVENTION

The present invention relates to the field of lenticular optics and, in particular, to the manufacture and use of lenticular optical systems in printed matter in which a lenticular lens overlays one or more composite designs so that the designs are visible or invisible depending on the viewing angle.

BACKGROUND OF THE INVENTION

Lenticular lenses have been used for many years to produce interesting and useful optical effects. Typical lenticular lens systems include a transparent sheet of plastic or other material with a flat surface on one side and a set of parallel grooves on the other side. The grooves are roughly parabolic or semicircular in cross section so that each groove disperses light like a lens. On the flat side of the sheet is a design formed of a composite of lines. The lines of the design composite are positioned parallel to the grooves to take advantage of the light dispersion of the grooves. In this way, the design composite is visible from certain viewing angles but not from other viewing angles.

The system may employ one composite design or several depending on the desired effect. When only one design is used, the effect will be that the sheet shows the design from certain viewing angles but the sheet appears blank from other viewing angles. When more than one design is used, the effect will be that the sheet shows one design from certain viewing angles, another design from another viewing angle, and so on.

Lenticular optical systems are used in photographic applications, in television screens, for packaging, and for toys and novelties and other devices. Lenticular optical systems can also be used to create an image that appears to be three-

dimensional, by using one composite design positioned in relation to the parallel grooves such that it is visible to the left eye and a second composite design positioned in relation to the parallel grooves such that it is visible to the right eye.

The lenticular sheet may be mated with the design in several ways. One direct way is to simply print the design onto the flat side of the sheet. The design can then be covered with an opaque protective ink or other covering or can be left exposed for the transmission of light from behind the sheet through the flat side and out the grooved side. Another common way of mating the lenticular sheet with the design is to print the design onto a substrate and then adhere the sheet to the substrate. The substrate is commonly paper, but may also be a transparent or translucent material such as plastic to allow the transmission of light from the back of the lenticular sheet through the front. Yet another way of mating the lenticular sheet with the design is to apply the design to a substrate that is removable from the lenticular sheet and replaceable with another design, as shown in U.S. Patent No. 4,034,555 by Rosenthal, the contents of which are incorporated by reference.

A drawback to many lenticular optical systems is the difficulty and cost of manufacturing the lenticular sheet and precisely mating the lenticular sheet with the designs so that the designs are viewable from the chosen viewing angles and only those angles. Lenticular sheets currently are manufactured using plastic extrusion techniques in which the groves of the sheet are produced by extruding the sheet through an extrusion die, using a grooved cylindrical die to form grooves onto the molten plastic by moving the sheet over the rotating cylinder, or using techniques

involving hot stamping the grooves into stampable sheet material such as PVC vinyl. Each of these approaches is somewhat costly, and still requires the additional step of producing the designs and precisely mating the lenticular sheet with the designs. This leads to unacceptably large indexing errors over a short length of lens such as 6 to 8 inches.

A number of apparatus are taught in U.S. Patent No. 3,241,429 by Rice et al. involving the embossing of lenticles onto a substrate. Rice teaches printing the side of the substrate that receives the embossed lenticles. A drawback to systems of the Rice type is that they generally require quite thick lenticles in order to provide the proper optical affect with respect to the printing; such thick lenticles are somewhat difficult to form. A further drawback to systems of the Rice type and other systems in the prior art is that the embossing system is difficult to operate properly to produce a good set of lenticles. Further, the embossing die is expensive to manufacture.

SUMMARY OF THE INVENTION

The present invention includes an economical and effective system for using printing press techniques to produce a lenticular sheet and to mate the lenticular sheet with one or more designs. The designs are applied to a substrate, and a set of transparent lenticles is applied to the substrate using a novel die. The printing may be done either before or after the lenticles are applied to the substrate, and may be done on either side of the substrate. Preferably, the transparent material is quick-setting such as ultraviolet-curable plastic.

The substrate may be an ordinary paper or other substrate, but is preferably transparent such as a

plastic sheet. If the substrate is paper or another common printing substrate, then the design would normally be printed on the side of the substrate that mates with the lenticular sheet that is applied to the substrate. If the substrate is transparent such as a plastic sheet, the substrate may be printed on either or both sides, with appropriate dimensional adjustments to the lenticular sheet and the composite lines of the design to produce the desired optical effect. If printed on the side away from the lenticles, the thickness of the transparent sheet can be used as part of the optical properties of the lenticles.

The system has the great advantage of providing a lenticular sheet that is economical and highly precise in its dimensions. Due to the very fast hardening of the quick-setting material, it can be manufactured in large quantities of sheets or rolls in a high speed process. In addition, by arranging the application of the lenticular sheet to the substrate in-line with the application of the design to the substrate, the entire manufacturing process becomes streamlined, allows the product to be manufactured with a minimum of handling, and avoids the necessity for re-registering the design with the lenticular sheet.

An aspect of the invention is the die used for applying the transparent lenticles to the substrate. Rather than using conventional machined or etched metal dies, the present invention utilizes a sheet of plastic that can be photographically etched such as brand name CYREL by Dupont. Although such materials are normally intended as simple ink-transfer devices it has ben found that they can be used as three-dimensional dies for applying lenticles in the manner of the present invention. Such an approach allows for the use of complicated optical patters rather than simple parallel

lines. This electronic fabrication also allows for highly precise indexing, so that the undesirable indexing errors of mechanically fabricated prior art systems are avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a lenticular sheet formed with a die cylinder in accordance with the present invention.

FIG. 2 is a diagrammatic view of a printing press for the present invention.

FIG. 3 is a detail from FIG. 2.

FIG. 4 is a detail from FIG. 2

FIGs. 5A - 5C are illustrative designs producible in accordance with the process of the invention.

DETAILED DESCRIPTION OF THE INVENTION

A cross-sectional view of a lenticular system in accordance with the present invention is shown in FIG. 1. The system includes a substrate 12 coated with a set of lenticular grooves 14. The substrate in a preferred embodiment is a transparent material such as transparent vinyl. Preferably, the substrate is printed on the side 16 away from the lenticular grooves. Alternatively, the substrate is printed on the side 18 to which the lenticular grooves are applied. Designs may also be applied to both sides 16 and 18. Whether the design is applied to one side or the other or both will dictate the substrate thickness and lenticular groove thickness and configuration that is required to obtain the desired optical properties, all in a manner well known in the art.

If the substrate 12 is printed on the side 16 away from the lenticles, as in the preferred embodiment

the thickness of the substrate 12 is employed as part of the lenticles. This can be important, because it allows the material 14 used to build-up the substrate 12 to form the lenticles 14, to be thinner and easier to apply. Further, if the side 16 of the substrate 12 away from the lenticles is printed, then the printing can be done either before or after the lenticles are applied to the substrate. If, as is typical in the art, the side 18 toward the lenticles is printed, then obviously the printing must be done before the lenticles are applied.

This is an important advantage for it allows the lenses to be premanufactured in large quantities with the attendant economics of scale, and then they can be printed on as needed, even for small projects. In contrast, in prior art systems such as the Rice patent mentioned above the substrate must be printed and then the lens formed onto the substrate. Setting up the lens-making operation involves substantial time, effort, cost and material waste, and is therefore not economical for a small project.

Although the preferred embodiment uses transparent vinyl as the substrate, it will be apparent that the substrate could also be an opaque material such as paper, provided that the design is then applied to the substrate side 18 that receives the lenticular grooves. The design itself is applied as a composite of lines running parallel to the lenticular grooves in the manner known in the art, so that the lines of each design are visible from chosen viewing angles but not from other viewing angles. By alternating the composite of lines of more than one design, the system can achieve an optical effect in which one design is visible from certain viewing angles, and another design is visible from other viewing angles.

The coating of lenticular grooves 18 on the substrate is preferably a quick-setting transparent material such as ultraviolet-curable plastic. The material is applied directly to the substrate, the grooves are formed, and the material is cured in the manner described below.

A diagram of a portion of a modified printing press used to apply the lenticular grooves to the substrate is shown in FIG. 2.

An impression cylinder 32 and a die cylinder 34 draw substrate (not shown) between them in the path indicated by the arrows 36, and discharge the substrate along the path indicated approximately by the arrow 38. Of course, the impression cylinder 32 may cooperatively engage other cylinders (not shown) in moving substrate through the mechanism, in the typical manners known in the printing art. A coating reservoir 40 is positioned at the top of the die cylinder 34. The coating reservoir 40 includes a bottom 42 which is positioned immediately adjacent the top surface of the die cylinder 34 and a wall 46. Attached to the coating reservoir 40, on the inner side of the wall 46 in the preferred embodiment shown, is a flexible strip 44 extending the width of the die cylinder 34.

The strip 44 is flexed against the die cylinder 34 in the manner of a "squeegee". The coating reservoir 40 holds a quantity of liquid coating material 50. The coating material 50 is preferably an ultraviolet curable liquid such as Pierce & Steven's 9013 UV coating.

The ultraviolet curable liquid 50 is of a viscosity such that it flows past the strip 44 and onto the die cylinder 34. As the die cylinder 34 rotates in the direction of the arrow shown, the ultraviolet curable liquid 50 is smoothed to a thin plastic coating

52 on the die cylinder 34, as better shown in FIG. 3. FIG. 3 is a detailed view of the coating reservoir 40 mounted to the die cylinder 34. Also shown in FIG. 3 is the die itself 36 which overlays the die cylinder 34. It can be seen from FIG. 3 that the ultraviolet curable liquid 50 is sufficiently viscus that it does not flow uncontrolled over the die cylinder 34.

In the simple drawing of FIG. 2, the coating reservoir 40 as shown containing the ultraviolet curable liquid 50 in a manner allowing the gravity flow of the ultraviolet curable liquid 50 onto the die cylinder 34. However, it can be appreciated that the coating reservoir 40 may be modified so that coating material 50 is periodically or continuously pumped from a separate, larger coating reservoir or supply drum. Further, the application of the ultraviolet curable liquid 50 to the die cylinder 34 may be accomplished wholly or partly by positive application through a pump or other means rather than by a simple gravity flow system. In any event, the principle of applying the ultraviolet curable liquid 50 to the die cylinder 34 and smoothing the applied liquid to a thin film 52 using the flexible strip 44 or some other means, is still the same.

FIG. 4 shows the interface between the die cylinder 34 and the impression cylinder 32 through which the substrate 60 passes. As can be seen, the ultraviolet curable liquid film 50 on the die cylinder 34 (specifically on the die 36 overlying the die cylinder 34) contacts the surface of the substrate 60 at the interface between the two rollers. The ultraviolet curable liquid film 50 then adheres the substrate 60 and detaches from the die 36 as it exist the space between the die cylinder 34 and impression cylinder 32.

Once the ultraviolet-curable liquid film 50 is applied from the die 36 to the substrate 60, and the substrate 60 exits the cylinders 34 and 32, it is passed under an ultraviolet light (not shown) to be hardened very quickly so that the substrate with applied lenticular material can be stacked or rolled. The ultraviolet light is positioned on the lenticle side of the substrate.

In a preferred embodiment, the substrate 60 is rigid polyvinylchloride, approximately .015 inches thick. The ultraviolet curable liquid and is applied to a thickness of .0025 inches at the top of the grooves and less than .001 inches at the bottom of the grooves. Of course, other materials and dimensions may be useful as well to accomplish the same result.

The die 36 is fabricated and used in a manner previously unknown in the art. (Additionally, such dies may be manufactured by machining or etching.) It has been found that a material known as CYREL brand by Dupont can be used to create a die. Such material is normally used as a simple ink transfer device. Patterns in the material are produced by well known photographic etching techniques. The etched material thus forms a pattern of raised and recessed areas, wherein the raised areas are inked for application to a substrate.

It has surprisingly been found that CYREL brand material by Dupont can be etched to form a three dimensional die, rather than simply etched to form a pattern of raised and recessed areas for simple ink transfer. To form a three dimensional die, the die pattern is produced using art work or by computer-generated processes. In the case of a die which constitutes parallel grooves, such as the die used to produce parallel lenticles in accordance with the

present invention, the negative is a simple series of parallel spaced lines. That negative is photographically etched onto the sheet. Rather than the etched sheet resulting in raised and recessed areas having abrupt discontinuities, it has been found that the sheet results in gradually inclined raised and recessed areas, connected by parabolic or semicircular lines. These parabolic or semicircular surfaces act as near-perfect die surfaces to produce a lenticle.

A distinct advantage to dies produced in accordance with the process described above is that they are very inexpensive to produce. Rather than machining or etching a cylinder, one need only photographically etch a inexpensive sheet. As a result, it is very simple and inexpensive to experiment with different lenticle sizes and spacing. Another important advantage of such a process is that it allows the production of complicated die patterns very easily. In the prior art, such complicated patterns required complicated etching or engraving of cylinders. In the present process, such complicated patterns can be produced in die form as easily as simple patterns, once the pattern itself is produced artistically or by computer graphics. FIGs. 5A, B and C depict several of the infinite variety of patterns that can easily be produced as a die in accordance with the process.

In the embodiment described above, the lenticular material is applied in grooves to the substrate and the finished substrate is then stored for use later in printing composite designs onto the substrate. It is also possible to arrange the design printers in-line with the printer used for the lenticular material. In this manner, the system is manufactured in a single process so that there is no intermediate handling and storage step, and no need to

re-register the substrate after the lenticular material is applied and before the substrate is printed with composite designs.

CLAIMS

1. A method of producing a lenticular optical design, comprising: applying a liquid film to a die; applying said die with said liquid film applied thereto to a substrate to transfer the liquid film to the substrate; hardening the liquid film applied to the substrate; and printing the substrate.

2. The method of claim 1, wherein the substrate is printed before the liquid flow is applied.

3. The method of claim 2, wherein the substrate has a side to which the liquid film is applied, and wherein such side is printed.

4. The method of claim 1, wherein the substrate has a side to which the liquid film is not applied, and such side is printed.

5. The method of claim 1, wherein the liquid film is ultraviolet-curable plastic, and the hardening step is by exposing the liquid film to ultraviolet light.

6. The method of claim 1, wherein the die is on a cylinder, and the liquid film is applied by flowing liquid onto the cylinder and smoothing the liquid into a film by applying a flexible strip to the cylinder while rotating the cylinder.

6. The method of claim 5, wherein said cylinder is a die cylinder, and a second cylinder is rotated adjacent the die cylinder whereby the substrate is drawn between the die cylinder and the second cylinder so that the liquid film is applied from the die cylinder to the substrate.

7. The method of claim 6, wherein the die cylinder includes a flexible die overlying a cylindrical element, and wherein the flexible die is a photographically etched plastic sheet.

8. The method of claim 7, wherein the

photographically etched plastic sheet is made by producing a photographic negative and etching said sheet using the photographic negative.

9. The method of claim 8, wherein said photographic negative is computer-generated.

10. An apparatus for producing a lenticular optical system, comprising: a die having a plurality of lenticle patterns; a reservoir of curable liquid; a liquid applier for applying a film of said liquid to said die; and a substrate engager for engaging a substrate and positioning said substrate to receive the liquid film from the die.

11. The apparatus of claim 10, wherein said die includes a die cylinder and an overlying removable die element.

12. The apparatus of claim 11, wherein said overlying removable die element is a photographically etched plastic sheet.

13. The apparatus of claim 12, wherein the substrate engager is a substrate cylinder positioned adjacent the die cylinder so that the substrate cylinder and the die cylinder rotate in opposite directions to draw the substrate between them.

14. The apparatus of claim 10, wherein the liquid applier includes a liquid reservoir and a flexible strip biased against the die to apply the liquid and to smooth the liquid to a film.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/08471

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :C08J 7/04; B29D 11/00, 7/01; B05D 5/00, 5/06; B05C 1/00, 11/02
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS (Search terms: liquid#, solution#, transfer?, optic?, die#, roll? cylinder#, lentical?, UV, ultraviolet, ultra violet, radiat?, irradiat?)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A, 4,933,120 (D'Amato et al) 12 June 1990, see Abstract; Figures 2 and 3; col. 5, line 24-col. 6, line 15; col. 4, lines 14-68 and col. 3, lines 15-21.	1-13
Y	US,A, 4,932,685 (Mancuso) 12 June 1990, see Abstract; Figure 16, and col. 1, lines 44-59.	1-10
P,Y	US,A, 5,330,799 (Sandor et al) 19 July 1994, see Abstract; Figure 7a, 8, 9, 11 and 12.	1-13
A	US,A, 3,956,091 (Polichette et al) 11 May 1976, see entire document.	1-9
X ---- Y	US,A, 5,281,373 (Tamura et al) 25 January 1994, see Abstract; Figure 1-2,4-5,8a; col. 4, lines 31-col. 6, line 14.	10 ----- 11-13

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A, 4,141,313 (Hefele) 27 February 1979, see Abstract; Figures 1-5.	10-11, 13-14
Y	US,A, 3,814,052 (Caratsch) 04 June 1994, see Abstract; Figure; col. 2 line 56-col. 3, line 22.	10-11, 13-14
Y	US,A, 3,762,365 (Herzog) 02 October 1973, see Abstract and Figures 1 and 2.	10-11, 13-14
A	US,A, 3,630,835 (Busch) 28 December 1971, see Figures 1 and 3.	10-11 13-14
A	US,A, 4,357,370 (Alheid) 02 November 1982, see Figure.	10-11, 13-14
Y	US,A, 3,552,353 (Lobombarde) 05 January 1971, see all figures, esp. 8-9, 13 and 15; Abstract.	10-11, 13-14
Y	US,A, 5,234,521 (Groshens et al) 10 August 1993, see Abstract, Figure .	10-13

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

427/510, 511, 512, 162, 264, 278, 164, 169; 118/106, 112, 116, 117, 206, 211, 212, 231; 264/1.1, 1.32, 1.34, 1.38, 1.6, 2.1, 2.3

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

427/510, 511, 512, 162, 164, 169, 264, 273, 274, 277, 278; 118/44, 45, 620, 102, 103, 106, 112, 116, 117, 206, 211, 212, 230, 231; 264/1.1, 1.32, 1.34, 1.38, 1.6, 2.1, 2.3